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## Effect of turbulent length scale on a wind turbine aerofoil

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**Summary.** Wind Energy represents the most technically advanced and diffused renewable resource. The lack of available sites for on-shore wind farms has spurred interest for unconventional locations, such as the urban environment. As production coincides with consumption, urban wind energy might reduce infrastructural costs associated to traditional sites. However, hardly few (if any) applications have so far succeeded in providing a reliable source of power output, fostering scepticism towards the whole wind energy sector. This might be attributed to the lack in understanding of the performance of wind turbines in the highly turbulent inflow present in the built environment. Therefore, a “back to basics” approach is needed to understand the effect of a turbulent inflow on the aerodynamic performance of wind turbine aerofoils. One particularly disguised issue is the effect of the integral length scale towards the negligibility of the effects of turbulence. A wind turbine aerofoil model with chord  $c$  is therefore tested in the wind tunnel under different turbulent inflows, where turbulence intensity ( $I$ ) and integral length scale ( $LS$ ), are varied independently. Unlike what it is stated in literature, results might suggest that an effect of turbulence is noticed even if  $LS \gg c$ .

**Introduction.** Wind energy is steadily settling its prominent position in the energy provision market [1], being rightly considered the most reliable and readily available non-fossil source of energy [2]. While many suitable locations are becoming unavailable, at least three wind energy trends are perceptible, i.e. building larger converters, new more performant typologies and exploiting unconventional locations. The urban environment presents some interesting features for urban wind energy (UWE) such as the local increase in the mean velocity [3]. However, due to the many obstacles wind encounters, free stream turbulence (FST) is highly enhanced [4]. As a result, the performance of converter is heavily affected leading to a chronic inefficiency of the technology due to the poor power production [5]. Although the aerodynamic performance is mostly responsible for this issue [6], only few studies have concentrated on the topic, so far giving few indications to designers (table 1). This might be largely explained with the difficulty in controlling turbulence characteristics at the inlet of both wind tunnel and numerical models [7].

Table 1 – Experiments on effect of turbulent inflow on WT blades: PG/AG Active/Passive grid, pt pressure taps

Authors/year	chord $c$ [m]	grid type	t. int. $I$ [%]	len. sc. $LS$ [m]	measures	Notes
Devinant et al. 2002 [8]	0.3	PG	16	-	43 pt	-
Amandolèse and Széchenyi, 2004 [9]	0.5	PG	7.5	-	25 pt	oscillating aerofoil
Swalwell et al., 2004 [10]	0.125	PG	13	0.16	28 pt	thick aerofoil
Sicot et al., 2006 [11]	0.3-0.07*	PG	16	-	43 pt; PIV*	*small blade for PIV
Maldonado et al., 2015 [12]	0.25	AG	6.1	0.15	32 pt	Rough blade
Li et al., 2016 [13]	0.14	PG	13.9	-	46 pt	Low Re custom. blade

**Effect of the integral length scale of turbulence on a wind turbine aerofoil.** In this study, the effect of turbulence on the aerodynamic performance of a typical wind turbine aerofoil with chord  $c$  is investigated in the wind tunnel. The aim is to understand whether the effect of turbulence is negligible based on the integral length scale  $LS$  of turbulence. In fact, FST causes a delay in aerofoil stall and an increase in Lift and aerodynamic performance due to the increased transport of momentum for the boundary layer [14]. However, it is debatable whether this is the case for  $LS \gg c$ . To investigate this, a set of passive grids has been developed so that  $I$  and  $LS$  are varied independently (fig. 1a). The

grids, with varying porosity  $\beta \sim 0.5-0.65$  have been alternately placed at the inlet nozzle of the University of Liège Wind Tunnel Lab (Belgium), where the experiment has been conducted. The presence of an expansion in the wind tunnel test section has greatly helped in achieving  $LS \sim 30$  cm together with  $I \sim 15\%$ . As it experiences a smooth stall mechanism, and it is optimised towards roughness insensitiveness, the Delft wind turbine aerofoil *DU96w180* is tested for  $\alpha = 4-14-24$  deg. To fulfil the aim, a value of  $c < LS/2$  should be at least aimed. Therefore, two models with  $c = 0.125$  and  $0.05$  m have been chosen for the experiment. The model (fig. 1b) has been printed with selective laser sintering, along with 40 pressure taps for the measurements of the fluctuating pressure field (fig. 1c). Reynolds effects might be present due to the low Reynolds number range used, i.e.  $Re \sim 15'000-25'000$ . However, these seem to disappear when turbulence is introduced in the inflow. Preliminary results are shown in figure 1d. The integral length scale seems to catalyse the effect of FST in the aerodynamic performance at least for small angles of attack, which is compatible with the annulment of Reynolds effects. These results emphasise the importance of research in the topic of bluff body aerodynamics and the effect of turbulence on the aerodynamic performance. The expected output is an improvement of 2D aerofoil data to account for the effect of turbulence in the design of efficient urban wind turbines.



Figure 1. a) Schematic of passive grid used to generate inflow turbulence; b), c) experimental setup at the university of Liège; d) preliminary results showing the effect of LS.

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